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Prediction of Survival After 48-h of Intensive Care Following Open Surgical Repair of Ruptured Abdominal Aortic Aneurysm

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Objective. *To identify predictive factors for 30-day mortality after 48 h of maximal treatment in intensive care unit (ICU) after repair for ruptured abdominal aortic aneurysm (RAAA).*
Design. *Retrospective study in the ICU of the university central hospital.*
Materials and methods. *Between 1999 and 2003, a total of 197 patients were admitted to emergency unit due to RAAA, and 185 of them underwent open surgical repair. A total of 138 patients survived at least 48-h and were included in a study to identify factors predictive of 30-day mortality by logistic regression analysis.*
Results. *Thirty-day mortality of all RAAA patients was 46% (87/197) whereas the 30-day mortality for those alive at 48 h was 22% (31/138). Forward stepwise multivariate logistic regression analysis revealed that only organ dysfunction by SOFA score (sequential organ failure assessment) at 48-h, preoperative Glasgow Aneurysm Score, and supra-renal clamping in operation were independent predictors of death.*
Conclusions. *Degree of organ dysfunction by SOFA score was the best predictor of 30-day mortality in RAAA patients alive at 48-h after open surgical repair.*

Keywords: Ruptured abdominal aortic aneurysm; Hospital mortality; Outcome; Sequential organ failure assessment score; Glasgow Aneurysm Score; Organ dysfunction.

Introduction

Mortality after repair of ruptured abdominal aortic aneurysm (RAAA) remains high, 40–50%.[1] When prehospital deaths and untreated hospital RAAA patients are included, total RAAA mortality is as high as 70–90%.[2–4] Several studies have focused on identifying preoperative factors and measurements which would reliably predict poor outcome or indicate a threshold for the decision not to operate.[5–9] Hardman *et al.* found out that the following factors predict RAAA mortality: Age >76 years, loss of consciousness, ischaemia confirmed by electrocardiogram, creatinine level >180 μmol/l, and haemoglobin < 90 g/l.[5] A score of three or more of these factors predicted 100% mortality.[5,6] Samy *et al.* developed and validated Glasgow Aneurysm Score for both elective and ruptured AAA patients.[7,8] Korhonen *et al.* showed that for the Glasgow Aneurysm Score also predicted mortality after RAAA repair.[9] The decision whether or not to operate still remains clinical, as validated guidelines do not exist.

Operative mortality after repair for RAAA can be divided into early and late deaths. Early deaths occur within 48 h after surgery.[10–12] These deaths are usually results of the rupture and hemorrhagic shock. Multiple organ dysfunction is the usual cause of death after immediate postoperative period. Bown *et al.* showed that factors related to postoperative death after 24 h are different from those previously found to be associated overall mortality after RAAA repair.[10] Significant factors associated with mortality more than 24 h after RAAA repair were low blood pressure intra-operatively, the need for consultant anaesthesiologist to be present at operation and also cardiac, renal or gastro-intestinal complications.[10] Other studies showed that multi-organ dysfunction score (MOD) differed significantly between survivors and

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non-survivors after 48 h.[11,12] MOD score ≥ 4 predicted mortality, renal and liver dysfunction being particularly important.[11,12]

The policy in Department of Vascular Surgery in Helsinki University Central Hospital is to try to save all RAAA patients by open surgical repair. Some of the patients die intra-operatively whereas the others die days or weeks later despite of intensive care unit (ICU) treatment. It remains important to identify whether late deaths can be predicted, so that unnecessary prolonged treatment can be avoided. In the early postoperative period, at least 24–48 h there should be full supportive treatment in the ICU. The decision whether to withdraw or continue treatment should be taken only after some days of optimal treatment in the ICU. This study was designed to identify factors, which could reliably predict 30-day mortality in those RAAA patients alive at 48 h after open surgical repair.

Material and Methods

The study included all patients admitted for RAAA in the Department of Surgery, Helsinki University Central Hospital during the years 1999–2003. The hospital records of these patients were reviewed retrospectively and patients were included in the analysis only if rupture was confirmed at laparotomy or at autopsy. Only patients with open surgery were included. Death certificates of RAAA patients were checked with the Central Statistical Office of Finland (Statistics Finland) to determine 30-day mortality for all RAAA patients. The analysis of postoperative predictors and mortality was restricted to those patients surviving until 48 h after surgery, using risk factors identified in previous studies.[11,12] After repair of RAAA 135 patients were treated in the ICU. Only three of 138 RAAA patients were not admitted to ICU, all three survived.

Data of the patients consisted of co-morbidities, preoperative factors at emergency unit, intra- and postoperative factors (Table 1). Altogether 122 factors were reviewed from 138 patients. Only 3.7% data were missing. Sequential organ failure assessment (SOFA) was used for organ dysfunction assessment.[13] SOFA scores were calculated postoperatively at day 1, 2 (48 h), 3, 7, 14, and 21 as long as patients were in the hospital. If a laboratory value was missing, the previous day's value was used, and if the previous day's value was not available, the next day's value was used. If both of these values were missing 2 days earlier or 2 days ahead values were used, respectively. If all these values were missing, the value was considered missing and was calculated as a normal value. Glasgow coma scale was considered to be normal in sedated patients, if there was no known cause for abnormality.

Organ dysfunction were defined as a SOFA score (score 0–4): PaO_2/FiO_2 for respiratory failure; creatinine level, urine output, or renal hemofiltration or -dialysis for renal; bilirubin for liver; epinephrine or norepinephrine administered for cardiovascular; platelet count for coagulation; and Glasgow coma scale for central nervous system dysfunction (Table 2).[13]

The preoperative Glasgow Aneurysm Score for each RAAA patient was calculated according to the previously published[7] and validated[8] formula: Risk score = (age in years) + (17 points for shock) + (7 points for myocardial disease) + (10 points for cerebrovascular disease) + (14 points for renal disease, including history of chronic or acute failure and/or urea > 20 mmol/l and/or creatinine > 150 μmol/l).

Statistical analysis was performed with the SPSS statistical program (SPSS version 11.0, Chicago, IL, USA). Continuous variables between non-survivors and survivors were first compared with the nonparametric Mann–Whitney *U*-test. Dichotomous variables were compared by Fisher's exact test. Univariate analysis examining the association between 30-day mortality and preoperative Glasgow Aneurysm Score, several intra-operative, and postoperative factors was carried out (Table 1). Thereafter, forward stepwise multiple logistic regression analysis was performed to evaluate the independent effect of significant factors detected in univariate analysis. The correct classification rate (CCR) for the best model is reported. Thereafter, the discriminative power (ability to distinguish between patients who die and those who survive) of independent predictive factors was evaluated by calculating the area under the receiver operating characteristic curves (AUCs). In all analyses a p-value < 0.05 was considered statistically significant.

Results

A total of 197 patients were admitted to the emergency unit of the Department of Surgery for RAAA. The 30-day mortality of all RAAA patients was 46% (90/197). Three of the patients died in hospital beyond 30 days: At days 64, 72, and 79. Of these 197 patients 185 (94%) patients underwent open surgery (Fig. 1). Of the 12 patients (6%) not treated five were considered moribund and not candidates for surgery and seven patients had different primary diagnosis, without vascular consultation, and were found to have RAAA as the cause of death at autopsy. There were 19 deaths intra-operatively and 28 patients died within

Table 1. Recorded data for each patient (where available)

General data	Co-morbidities	Preoperative factors	Intra-operative factors	Postoperative factors
Age	Diabetes	Hemoglobin	Bleeding	Reoperation
Gender	Lung disease (if on medication)	Platelets	Amount of blood transfusion	Renal insufficiency
AAA known	Hypertension	Creatinine	Amount of fluids	Dialysis
AAA diameter	Myocardial disease	Lowest blood pressure at ER	Urine output	AMI (troponine > 0.5 μmol/l
Outcome	Chronic renal disease	Ischemia in ECG	Suprarenel claming time	Stroke (CT diagnosed)
Days in ICU	Chronic dialysis, heart failure	Troponine level	IMA or RA reconstruction	SOFA scores
Time to death/discharge	Cerebrovascular disease	Cardiac arrest	Duration of procedure	Creatinine
	General arteriosclerosis	Shock (SAP < 90 mmHg)	Type of reconstruction	Lactate
		Glasgow coma scale	Senior anesthesiologist present	
		Glasgow Aneurysm Score		

AAA, abdominal aortic aneurysm; SAP, systolic blood pressure; EKG, electrocardiograph; ER, emergency room; IMA, inferior mesenteric artery; RA, renal artery; AMI, acute myocardial infarction; CT, computer tomography; SOFA, sequential organ failure assessment.

48 h postoperatively. Those 138 patients who survived 48 h after surgery were studied further, their 30-day mortality was 22% (31/138).

Of the 138 patients 21 were female (15%) and 117 male (85%). Mean age was 71 years (median 71, and range 42–92). Demographic data, co-morbidities and preoperative factors of these patients are presented in Table 3. The mean length of ICU stay was 7 days for survivors (median 4, range 0–35 days) and 8 days (median 6, range 2–22 days) for non-survivors ($p=0.13$). Supra-renal clamping was used in 20 (19%) of the 107 survivors and in 13 (42%) of the 31 non-survivors ($p=0.009$ by 2-tail Fisher test). Supra-renal clamping was necessary for specific anatomical or bleeding conditions. Two survivors and two non-survivors with suprarenal clamping underwent renal artery reconstruction. The results of the univariate analysis of preoperative Glasgow Aneurysm Score, intra-operative, and 48 h postoperative factors recorded are shown in Table 4.

In the multiple logistic regression analysis SOFA score at day 2 (48 h) ($p<0.001$), preoperative Glasgow Aneurysm Score ($p=0.03$), and supra-renal clamping ($p=0.04$) were independent predictors of the late postoperative mortality. The CCR for this model was 83%. The areas under the receiver operating characteristic curves (AUC) of significant measures of multivariate analysis were 0.79 (95% CI 0.70–0.89) for day 2 SOFA score, and 0.67 (95% CI 0.56–0.78) for preoperative Glasgow Aneurysm Score, respectively. At day 2 (48 h) cut-off value for SOFA score >11 predicted mortality with a sensitivity of 39% and a specificity of 93%.

Daily SOFA scores for non-survivors and survivors are shown in Fig. 2. The mean maximum respiratory

Table 2. Sequential organ failure assessment (SOFA) score by Vincent *et al.*[13]

SOFA score	0	1	2	3	4
Respiration PaO_2/FiO_2 (mmHg)	>400	300–399	200–299	100–199	<100*
Coagulation platelets ($10^3/mm^3$)	>150	100–149	50–99	20–49	<20
Liver bilirubin, (mol/l)	<20	20–32	33–101	102–204	>204
Cardiovascular hypotension MAP (mmHg)	>70	<70	Dopamine or doputamine	Dopamine >5 or epinephrine ≤0.1 or norepinephrine ≤0.1†	Dopamine >15 or epinephrine >0.1 or norepinephrine >0.1†
Neurological Glasgow Coma Scale‡	15	13–14	10–12	6–9	<6
Renal creatinine (mol/l) or urine output/24 h	<110	110–170	171–299	300–440 <500 ml	>440 <200 ml or hemodialysis

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* With respiratory support.
† Adrenergic agent administered for at least 1 h (μg/kg/min).
‡ Without sedation.

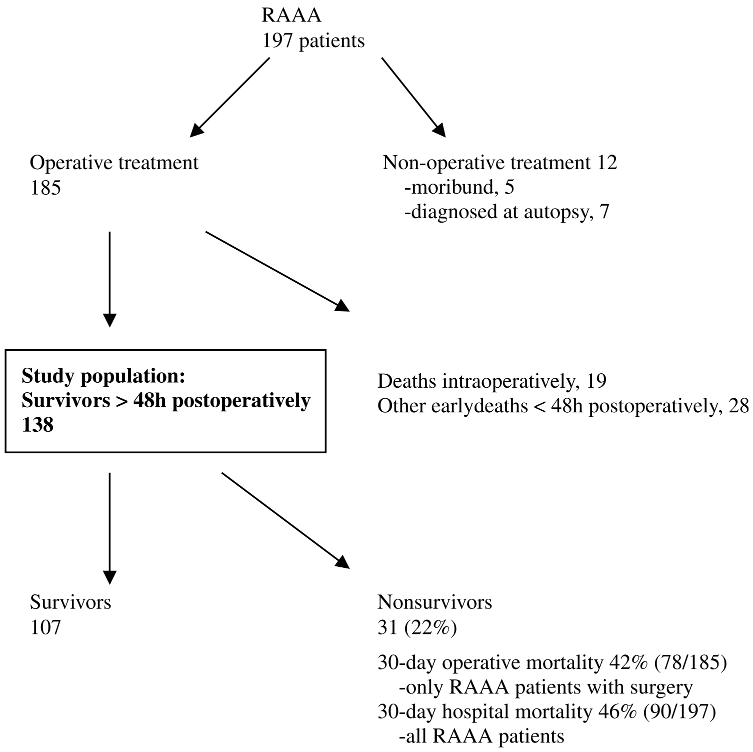

Fig. 1. Ruptured abdominal aortic aneurysm (RAAA) patients, 1999–2003.

(2.8, SE 0.2) and cardiovascular (3.1, SE 0.3) dysfunction scores were achieved at day 2. The mean maximum coagulation (1, 6, SE 0.2) dysfunction score was achieved at day 3, neurological (1.1, SE 0.6) at day 14, liver (2.5, SE 0.5) at day 21, and renal (4, SE 0.4) at day 21 (Fig. 3). The areas under the receiver operating characteristic curves (AUC) were for total SOFA scores daily: Day 1: 0.73 (95% CI 0.62–083), day 3: 0.83 (95% CI 0.74–0.93), day 7: 0.96 (95% CI 0.92–1.00), day 14: 0.91 (95% CI 0.80–1.02), day 21: 0.95 (95% CI 0.85–1.05). At day 7 cut-off value for SOFA score > 11 predicted mortality with a sensitivity of 63% and a specificity of 98%.

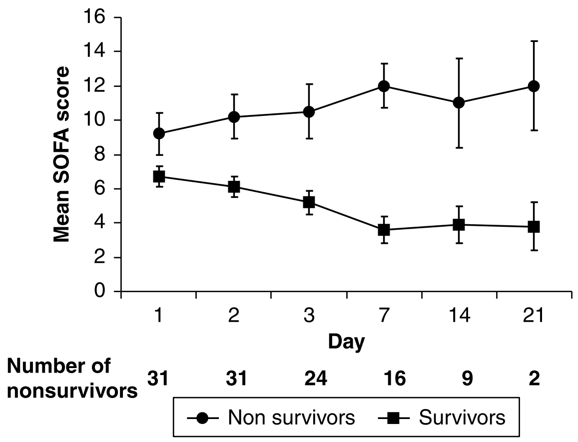

Fig. 2. Development of mean (95% confidence interval) daily sequential organ failure assessment (SOFA) score in 138 patients after repair of ruptured abdominal aortic aneurysm.

Discussion

Our study revealed that organ dysfunction by day 2 (48 h) SOFA score, supra-renal clamping during surgery and preoperative Glasgow Aneurysm Score were independent predictors of 30-day mortality in RAAA patients alive at 48-h after open surgical repair. These findings are similar to previous studies and show that factors influencing hospital mortality after 48-h from repair of RAAA are different from the factors influencing hospital mortality for all admitted RAAA patients.[10,12]

Haemorrhagic shock is usual cause of death perioperatively and immediately after surgery. In the ICU cause of death is more commonly caused by organ dysfunction. To best of our knowledge, this was the first study in which SOFA scores have been used to predict the hospital mortality after repair for RAAA. In previous prospective studies SOFA score has shown its potential to describe organ dysfunction in critically ill patients.[13,14] In emergency surgery for colorectal perforations the maximum SOFA score was a useful predictor for mortality.[15] Kniemeyer *et al.* and Maziak

Table 3. Demographic data, comorbidities, and preoperative factors for 138 ruptured abdominal aortic aneurysm patients who survived at least 48 h after surgery

Factor	Survivors	Non-survivors	*p*-value*
N	107	31	
Age (years, median, range)	70 (46–92)	74 (42–87)	0.01†
Female/male	16/91	5/26	1.00
Lung disease (%)	19 (18)	9 (29)	0.13
Hypertension (%)	57 (53)	16 (52)	1.00
Myocardial disease (%)	40 (37)	14 (45)	0.53
Renal disease/acute failure (%)	39 (36)	9 (29)	0.52
Cerebrovascular disease (%)	25 (23)	3 (10)	0.13
Haemoglobin (g/l), median (range)	98 (36–165)	86 (33–157)	0.08
Platelets $\times 10^9$, median (range)	178 (38–782)	164 (9–351)	0.22
Creatinine (μmol/l), median (range)	106 (55–259)	99 (68–278)	0.69
Shock (%)	40 (37)	20 (65)	0.01†
Glasgow Aneurysm Score, median (range)	83 (56–119)	95 (56–120)	0.005†

Thirty-day mortality is used.
* Mann–Whitney *U*-test for continuous variables and Fisher's exact test for dichotomous variables.
† $p<0.05$.

et al. used multiple organ dysfunction (MOD) score in their studies with 57 and 88 patients with RAAA, respectively.[11,12] With the MOD score organ dysfunction is assessed for the worst ICU day while SOFA score values are assigned daily, which is valuable in the standardised assessment of organ failure severity and duration.[16] Kniemeyer *et al.* suggested that for RAAA patients with a MOD score five or more the decision to terminate treatment is not controversial.[11] POSSUM scores are disease specific scoring systems but did not demonstrate good predictive value for delayed (beyond 24 h) mortality after repair of RAAA in the previous study of Bown *et al.*[10]

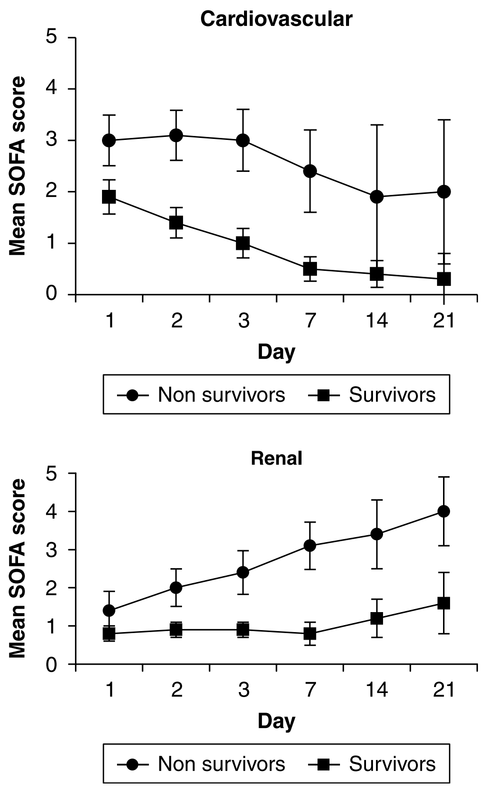

Fig. 3. Development of organ dysfunction by mean (95% confidence interval) sequential organ failure assessment (SOFA) scores (range, 0–4) in 138 patients after repair of ruptured abdominal aortic aneurysm.

Organ dysfunction is most predictive of 30-day mortality at 48 h after RAAA surgery. Daily measured SOFA scores showed that scores at day 7 had the best ability to discriminate between patients who die and those who survive, although, the number of non-survivors after day 7 was small ($n=16$). At day 2 (48 h) a SOFA score of >11 identified 39% of non-survivors but a SOFA score of >11 at day 7 identified 63% of non-survivors. Junger *et al.* used the maximum SOFA score and selected cut-off value ≥ 11.5 to predict mortality with a sensitivity of 37% and a specificity of 99% of unselected patients in surgical ICU.[17] Cabré *et al.* showed that 100% of unselected ICU patients aged over 60 years die, if the SOFA score remained above 10 for 5 days.[18]

Many attempts have been made to identify preoperative factors or measurement to predict RAAA mortality.[5–9] The Glasgow Aneurysm Score is useful tool in the emergency room to confirm the decision of whether to operate.[7–9] This study shows that the Glasgow Aneurysm Score also is valuable in predicting the postoperative outcome after open repair of RAAA. Similarly the Glasgow Aneurysm Score has been useful in stratifying the operative risk of patients undergoing elective open repair of AAA.[19]

Supra-renal clamping was an independent predictor of 30-day mortality in RAAA patients alive at 48 h after operation. A quarter of the patients had supra-renal clamping in the operation in our study. In elective operations supra-renal clamping is necessary in about 10%.[20,21] A previous study showed also that supra-renal clamping was used more often and

Table 4. Results of univariate analysis of preoperative Glasgow Aneurysm Score, intra-operative and 48-h postoperative factors, and 30-day mortality

Factor	*p*-value
Preoperative Glasgow Aneurysm Score	0.003*,†
Intra-operative blood loss	0.04*
Suprarenal clamping	0.01*,†
Renal artery reconstruction	0.29
Inferior mesenteric artery reconstruction	0.70
Duration of operation	0.99
Senior anaesthesiologist present at surgery	0.71
Reoperation <48 h postoperatively	0.006*
Reoperation due to bowel ischemia	0.003*
Acute myocardial infarction <48 h	0.49
Lactate maximal <48 h	<0.001‡
SOFA score, day 2 (48-h)	<0.001‡,†
Respiratory, day 2	0.02*
Renal, day 2	<0.001‡
Hepatic, day 2	0.23
Cardiovascular, day 2	0.001*
Coagulation, day 2	0.41
Neurological, day 2	0.14
Creatinine 48-h	0.001*
Platelets 48-h	0.72
Bilirubin 48-h	0.90

SOFA, sequential organ failure assessment.
* $p<0.05$.
† Independent factors in multivariate analysis.
‡ $p<0.001$.

peri-operative mortality was higher in urgent operations than in elective ones.[22] Supra-renal aortic clamping causes renal ischaemia and prolonged ischaemia may cause postoperative renal dysfunction.

The 22% 30-day mortality rate for survivors at 48 h in our study is comparable to previous reports. Bown *et al.* reported a 32% 30-day mortality for survivors at 24 h ($n=139$), Maziak *et al.* 23% for 48 h survivors ($n=69$), and Kniemeyer *et al.* 22% for 48 h survivors ($n=50$).[10–12]

Our study has some limitations. First, data collection was retrospective and doctors were not aware of the study. However, our results maybe reliable since, the amount of missing data was small. Second, because we did not collect the SOFA data daily (only days 1–3, 7, 14, 21), some valuable information may have been missed. Now daily SOFA scores are measured in the ICU and give us valuable information and the possibility of performing a new prospective study. In our opinion, this study was representative because of the high rates of operation and admission to ICU. However, the predictive factors identified should not be used in centres with a lower operative rate without external validation. In fact, in previous studies operative rates have been lower or not reported.[10–12]

In conclusion, the degree of organ dysfunction by the SOFA score was the strongest predictor of 30-day mortality in RAAA patients alive at 48 h after surgery. Preoperative Glasgow Aneurysm Score and supra-renal clamping in operation also were significant factors. Due to better discriminative power of SOFA score at day 7, the decision to withdraw intensive care after 48 h seems too early. However, a SOFA score of > 11 at day 7 still only has a sensitivity of 63% in predicting mortality, so that any decision to withdraw treatment remains difficult.

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